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WAVE-WASH CONTROL ON MISSISSIPPI RIVER LEVEES

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WATERWAYS DIVISION

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PAPERS

WAVE-WASH CONTROL ON MISSISSIPPI RIVER LEVEES

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Synopsis

Unprotected levees along the lower Mississippi River are subject to serious wave-wash damage where the foreshore is narrow and without protective vegetation. The need for protection works is almost continuous below New Orleans, La., and intermittent as far upstream as Baton Rouge, La. Above New Orleans the situation is less severe because ship traffic is lighter and the river banks are generally high enough to contain the river at ordinary stages, limiting wave-wash attack on the levees to periods of high water. Many types of protection have been suggested, and most of them have been tried, but no single type has met reasonable criteria for economy and effectiveness. Present practice (1953) is to use either of two major types of protection for the levee, and under special conditions, a supplemental structure to keep the wave-wash protection work from being undermined.

Conditions

Destructive waves in the river are caused by wind and passing ships. Storm damage is potentially most dangerous when river stages are high and wave-wash damage could weaken the levee sufficiently to cause a crevasse. Damage from ship wash is intermittent but cumulative, and in many places below New Orleans, can occur throughout the year. The levees in the lower river generally are built of clays that are rather resistant to erosion, and normal waves would seldom cause serious damage on sodded slopes of such materials if it were not for the effect of drift. Logs batter the face of the levee with considerable force, starting damage that ordinary wave action can then extend. A heavy log can seriously damage the less substantial forms of wave-wash protection, particularly when it becomes partly anchored and pounds repeatedly on the same spot. A secondary form of wave-wash damage occurs in several areas below New Orleans where the foreshore is low enough to be

submerged during much of the year and where the surface stratum consists of light, easily eroded soils. Protective vegetation will not grow in such locations and waves can break in the shallow water near the levee without restraint. Under such circumstances, the light surface soils are washed away and the wave-wash-protection structure is undermined.

Protection Works

Heavy protection works, as used on large earth dams, would be adequate for all levee purposes, but since levees aggregating more than 120 miles in the New Orleans district require such protection, and since the life expectancy of levees is limited by the meandering tendencies of the Mississippi River, it is apparent that a less expensive form of protection is necessary. The various formulas available for computing wave impact values are not useful in designing such works because the destructive potential of drift cannot be evaluated. It has been necessary, therefore, to examine earlier work and to experiment, adapting and improving the earlier designs, and discarding unsuccessful and unduly expensive features. By compensating for or eliminating weaknesses, designs have been developed which assure useful life commensurate with cost.

Emergency wave-wash protection works, used during floods to prevent development and extension of damage already incurred, include fences of wood and sheet piling, of light-gage steel, sacked earth, and riprap. These have value only for a limited range of river stages and are temporary since they must be removed when the levee is repaired. Another class of temporary protection includes old levees left standing between the new levee and the river, and debris from clearing and stripping operations piled riverward of the new levee borrow pit. These are destroyed by caving banks in a few years, but is is customary to get as much use as is practicable from these free protection works before permanent works are placed.

Permanent wave-wash protection works include wooden bulkheads or fences, generally called "wooden revetments," and various types of pavement applied to the river-side slope of the levee.

Wooden revetments, in a variety of types, have been used since the days of the first levees, and still protect more than fifty miles of levee in the New Orleans district. The type in current use has evolved over the years into a well-balanced structure capable of long and dependable service. It is subject, however, to hazards that cannot be eliminated in planning. Sound timber is always useful, and revetments frequently lose framing and planking by theft in the more isolated places. The braces interfere with proper mowing and maintenance of the river-side slope of the levee, and during the dry season, grass and trash fires sometimes are responsible for severe damage. Wooden revetments withstand attack well and are damaged only by heavy drift. Drift damage normally reduces but does not destroy the effectiveness of the revetment, and repairs can be made quickly, even during flood and storm conditions, without use of heavy mechanical equipment.

Three general types of pavement have been tried on a scale large enough to provide an adequate basis for preliminary evaluation. Various modifications of these basic types have shown no significant advantages in economy or performance.

Compacted asphaltic pavement, which is a densely-graded sheet asphalt 2.5 in. thick, containing approximately 10% asphalt cement, was used for some years as a by-product of the asphalt subaqueous and bank revetment operations. Natural deposits in bars provided aggregate; and loess deposits along the river provided filler. Construction was largely mechanized by use of modified road building equipment, though considerable hand work was necessary in the preliminary operations. The last levee pavement constructed by this method was placed in 1941, after which the equipment was diverted to military construction. The high density of the pavement made it quite effective in reducing the volume of seepage through the levee, but the thin pavement is extremely vulnerable to damage by drift, and maintenance has been expensive. Weathering and vegetation have caused further damage, and much of the pavement has deteriorated so far that further maintenance is impracticable.

Uncompacted asphaltic pavement was developed during World War II, when labor and equipment were scarce. It is poorly graded sand asphalt, 4.5 in. thick, containing 6% asphalt cement. The material is applied hot, then spread and roughly finished with rakes and shovels. No compaction is used. The pavement lacks the strength to withstand battering by drift, and because of the porosity resulting from coarse grading, low asphalt content, and lack of compaction, it has little value in reducing seepage and is particularly susceptible to damage by vegetation, which grows within and through the pavement. Although the weakness of the pavement has created a maintenance problem in exposed places, repair of local damage is simple and relatively inexpensive, and the pavement has performed adequately in light service.

Concrete pavement has been used successfully for many years, and several such pavements placed in the early years of the century are still (1953) in good condition. No record exists of such cast-in-place concrete pavement having failed under attack by waves and drift, though there have been failures caused by undermining. The principal objection to concrete has been its relatively high first cost. Probably unnecessary refinement of detail has contributed to high construction costs, and present (1953) construction is simply planned, using large panels of low-strength concrete with butt joints and screeded finish.

Undermining has become a major problem along shores below New Orleans with the gradual increase in ship traffic. In several areas where ship waves had caused severe washing of the foreshore, and undermining of the wave-wash protection works had occurred or was imminent, low brush dikes have been constructed between the levee and the river to break up waves before they reach the levee. When stages are appreciably higher than the top of the dike, the depth of water over the foreshore is sufficient to cushion the impact of the waves. Cross dikes act as retards and induce deposit of river-borne sediment near the levee during high water periods.

The wooden revetment shown in Fig. 1 is constructed of No. 2 common rough pine lumber that is given a 10-lb open-cell creosote treatment after being cut to size. Planking is 2 in. thick, and from 8 in. to 12 in. wide. The posts are capped with sheet metal or bituminous material. Anchors are buried deeply in the levee and are designed to resist tension in the braces as well as normal forces, since anchors of earlier design have failed when large waves

rolled over and pushed out the revetment from behind. Major connections are made with bolts with cast iron ogee washers.

The top of the planking is 2 ft above the maximum flow line; the bottom is generally 3 ft below ground surface, with increased penetration where undermining is possible. Penetration of the posts is approximately 1.5 ft more than that of the planking. The batter of the face of the revetment is 6 vertical on 1 horizontal; slope of bracing is not steeper than 1 vertical on 3 horizontal. An intermediate rail is provided when the top and bottom rails are more than 7 ft apart.

Fig. 2 shows a wooden revetment in excellent condition about three years after construction. The heavy growth of Johnson grass on the levee slope is typical of such installations because the braces interfere with the use of powered mowing equipment.

Fig. 3 shows a section of concrete pavement of current (1953) design. The slab has an average thickness of 4 in.; the minimum acceptable thickness is 3.5 in. A cut-off wall is provided at the top to prevent infiltration of rain water from the slope and crown above. The toe of the slab is placed at least 3 ft below natural ground surface, and the toe trench is backfilled with earth. A longitudinal expansion joint is provided near the ground surface to allow for some settlement in the levee embankment without damage to the pavement. This and other necessary extension joints are made with premoulded mastic or cypress boards with suitable seal. The maximum permissible panel size on old, well-compacted earth surfaces, is 40 ft by 40 ft. Smaller panels must be used on fresh fills. The average compressive strength of the concrete is 2,000 lb per sq in.

Fig. 4 shows concrete pavement seven years old. This pavement was constructed with small panels separated by thin expansion joints made with asphalted felt. The joints are not tight and grass and weeds grow through them. No damage from vegetation has appeared in this particular pavement, but spalling has resulted from similar growth in some locations. This pavement is on an open reach of river and has been subjected to battering by the heaviest drift without visible damage.

A section of uncompacted asphaltic pavement is shown in Fig. 5. The design is similar to that of concrete pavement in regard to cut-off wall and toe penetration. The slab thickness averages 4.5 in., the minimum acceptable thickness being 4 in. The material is composed of sand aggregate that may contain as much as 30% gravel, with 6% by weight of asphalt cement having between 85 and 100 penetration. The graded earth surface receives a weed-killing treatment of sodium chlorate or salt before the pavement is placed.

Fig. 6 shows an uncompacted asphaltic pavement. In the foreground is a typical growth of Johnson grass, part of which has been recently mowed. In the middle distance is an area completely bare of vegetation; and brush and small willow trees have claimed the lower third of the levee slope. The entire area received the same treatment with sodium chlorate or salt. At this stage the pavement has not been seriously weakened by vegetation, but since every stalk, in pushing its way through the pavement, pulverizes and destroys the material in its path and breaks out a sizeable chip at the surface, the pavement becomes progressively more porous and correspondingly more vulnerable to

further growth. Perhaps only prohibitively expensive treatment would be completely effective in preventing damage of this kind. It is interesting to relate this problem to the successful use of thin asphaltic pavement for encouraging rapid production of protective sod on airfields and in ditch bottoms. Pavements containing a considerable volume of gravel seem to be somewhat less subject to damage by vegetation than the straight sand-asphalt pavements.

Fig. 7 shows a toe-wall used to repair pavement that has been undermined. Creosoted lumber sheathing is driven to a penetration of from 3 ft to 6 ft; the broken pavement is removed and placed as riprap riverward of the wall. Lost embankment is restored with a tamped earth backfill, and a new concrete slab is placed to join the toe-wall to the undisturbed slope pavement. An attempt has been made to control the conditions that make such work necessary, by construction of brush dikes as shown subsequently in Figs. 9 and 10.

Fig. 8 shows what happens to a weak pavement in an exposed location. Some of the drift that aggravates the situation can be seen on the levee slope; this is relatively small drift since the larger logs continue down the river to do damage elsewhere. The original pavement was compacted asphalt, which was seriously damaged by vegetation, waves, and drift. Extensive repairs were made with uncompacted asphalt, but further damage soon appeared in both the original pavement and in the patches. The foreshore was washed away intermittently by wave action at low river stages, and the pavement was undermined. The toe-wall treatment was applied where necessary and holes on the levee slope were patched with concrete. When the photograph was taken, new holes had appeared and the pavement obviously was beyond repair on any reasonable basis. Subsequently, a thin concrete slab has been placed on top of the old pavement to provide sufficient strength to prevent further damage by drift. It is probable (1953) that more toe-wall or brush dike construction will be necessary to prevent further undermining.

The form and positioning of brush dikes are illustrated by Fig. 9. Brush dikes vary in height from 3 ft to 6 ft, but are rarely more than 4 ft high for any considerable distance. The base width is 5 ft. A double row of light, untreated piling is driven with 5-ft transverse spacing and 10-ft longitudinal spacing. In the first stage of construction, piles in one row are driven to the full 15-ft penetration; those in the other row are left approximately 2 ft high. After the brush filling has been placed between the rows and the cables have been drawn up tight, the high piles are driven to full penetration to compress the filling and to produce the maximum practicable tension in the cables. In early plans for such dikes it was contemplated that drift would be used for filling, but it has been found both better and cheaper to cut willow brush and poles on bars where ample supplies are available, and to transport the material to the work site by barge. It is common practice to obtain brush and poles as far as fifty miles from the work site, and in one extreme case the contractor chose to get his material near Plaquemine, La., two hundred miles by river from the work. The lacing cable is $\frac{3}{4}$-in. seven-wire galvanized strand. Transverse ties, which are under somewhat greater stress during the redriving operation, are $\frac{1}{2}$-in. nineteen-wire galvanized strand. Railroad spikes are driven into the piles to hold the cables. The only major item of plant needed

for brush dike construction is a small dragline on a barge. Brush and poles are easily handled with slings and tongs. Piles are driven with a light hammer suspended from the boom. Much hand work is necessary, however—all of it wet and much of it difficult and aggravating.

Fig. 10 was taken in September, 1951, and shows a brush dike that was completed in January, 1951—just prior to the flood season, which was of long duration but not severe. Before construction of the dike the foreshore had been nearly denuded by low-water wave action; all vegetation had been washed away except for a few dying willow trees with exposed roots, and the wooden revetment was in imminent danger of being undermined. During the flood season following completion of the dike substantial deposits were made adjacent to the wooden revetment, ending any immediate threat of undermining. Some new growth is evident on the deposits, indicating that the foreshore is high enough to support vegetation.

Economics

For average conditions, where the total effective height of necessary protection works, including penetration, is 15 ft, comparative construction costs, adjusted to reflect 1953 contract prices plus engineering and overhead, are about $15 per lin ft for uncompacted asphalt pavement; $20 per lin ft for wooden revetment; and $25 per lin ft for concrete pavement. Brush dike, which belongs in a somewhat different category, costs about $8 per lin ft. First costs for the three principal classes are only superficially comparable, since circumstances and conditions may properly require the use of a particular one without regard to cost. Annual costs cannot be compared on any reasonable basis because of the wide variation in maintenance costs with the severity of exposure and the difficulty of establishing acceptable figures of life expectancy. If asphalt pavement is used in an exposed location, annual costs, because of the need for constant maintenance, may be several times as much as would have been the case if concrete pavement had been used. If, however, concrete pavement is placed on a levee that is destroyed by caving banks within a few years, the annual cost of concrete pavement could be considerably more than the annual cost of an asphalt pavement.

A reasonable estimate of life expectancy must be based on the rate of deterioration of the structure under normal conditions of use. It must be assumed that each structure is used only within the reasonable limits of its capabilities, and losses caused by river meander, fire, theft, and other considerations unrelated to wave-wash attack, must be excluded.

On this basis, it appears that a creosoted wooden revetment has a useful life of about twenty years. Within that period, replacement of broken, stolen, and deteriorated members is feasible and economical. After about twenty years complete replacement would normally be sound economy.

The first installation of uncompacted asphaltic pavement was made in 1944, and this type of pavement has not been in use long enough for failure to develop through deterioration alone. When used in locations where heavy drift cannot destroy it, it appears that the major factor affecting its useful life is the damage done by vegetation. On the basis of the damage now evident (1953) in the average 9-yr-old pavement in place, and assuming that the

pavement will become progressively more susceptible to damage by vegetation, it seems that disintegration will be so far advanced in ten years more that further maintenance will be impracticable. The useful life, therefore, appears to be not more than twenty years.

The useful life of concrete pavement appears to be determined by design and conditions of use rather than by the material. No significant deterioration of material is evident in pavements nearly fifty years old. It is probable, however, that in any reasonably economical design, infiltration of rain water and river water at the joints, over a long period of time, will produce cavities in the slopes large enough to cause the slabs to tilt and the joints to open. This is the only basis for estimating the useful life to be as short as forty years.

Conclusions

Uncompacted asphaltic pavement is the least expensive form of wave-wash protection in so far as first costs are concerned, and is adequate in areas where attack by waves and drift is not too severe. No extenisve new levee protection work has been done with this material since 1946, but uncompacted asphalt has been widely used in repair work and for river bank pavement that is deeply submerged at stages when drift is heavy. There may be economic justification for use of uncompacted asphalt pavement in semi-protected areas on levees whose life expectancy is less than twenty years.

Wooden revetments will continue in use. This is the only form of protection that can be constructed during high or rising river stages, and for that reason is used to advantage on embankments completed late in the working season, when construction of pavement might be interrupted by flood stages. Wooden revetments can be used on new embankment where the amount of shrinkage and subsidence expected would militate against early construction of pavement, and small isolated units can be economically constructed with hand tools where moblization of the plant needed for pavement construction would be prohibitively expensive.

Concrete pavement is the only type of protection in use that is able to withstand the heaviest attack. It is the only type that remains useful over a long period of time without regular maintenance. Where wave attack aggravated by drift would destroy a weaker structure, the use of concrete pavement is obviously essential, and its long life and low maintenance requirements seem to justify the relatively high first cost on any levee having an anticipated life in excess of twenty years.

Brush dikes are still in the experimental stage. In 1953 there is ample evidence that they have successfully accomplished their purpose in preventing undermining of wave-wash protection works and inducing deposit of river-borne material on submerged foreshore areas. The success is gratifying, but the rapid deterioration of the structures has resulted in heavy maintenance costs and it is apparent that a more durable structure is needed. The major factor in deterioration is the loss of brush filling, which is caused in part by failure to obtain adequate tensioning of cables and compression of the brush during construction, and in part by wave-wash, which causes sufficient scour under the dike to permit expansion of the brush filling and slackening of the cables. Permanent improvement of the low foreshore areas can be obtained

only if the dikes remain effective until the induced fill becomes consolidated and growth of vegetation produces natural protection against wave action. It is hoped, therefore, that improved methods of design and construction will produce more long-lived structures.

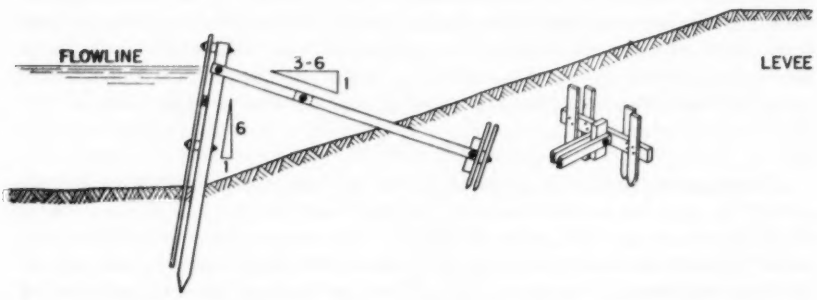

Fig. 1. Standard Wooden Revetment

Fig. 2. Revetment, Three Years Old

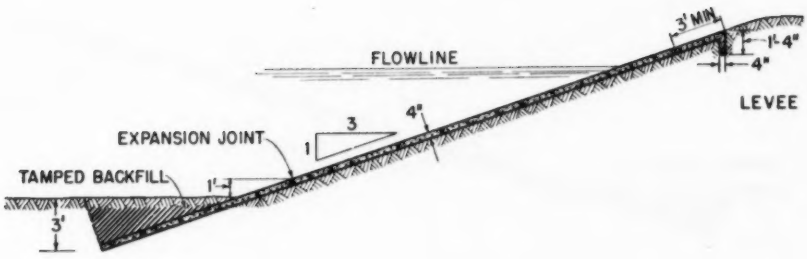

Fig. 3. Cross Section Through Concrete Slope Pavement

Fig. 4. Concrete Slope Pavement

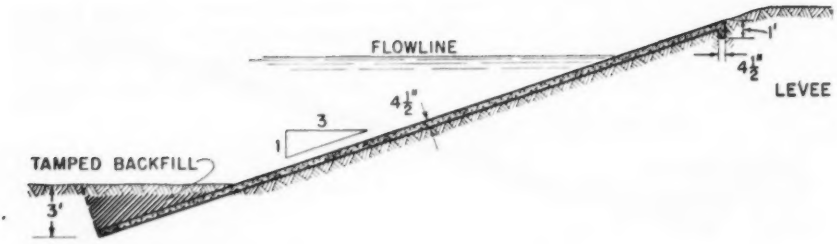

Fig. 5. Cross Section Through Uncompacted Asphalt Slope Pavement

Fig. 6. Uncompacted Asphalt Slope Pavement

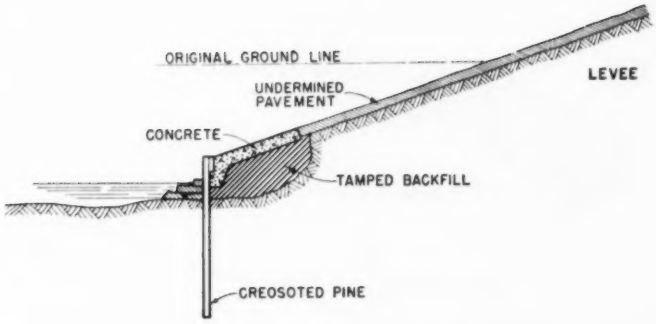

Fig. 7. Slope Pavement Repair Using a Timber Toe-Wall

Fig. 8. Weak, Exposed Asphalt Pavement

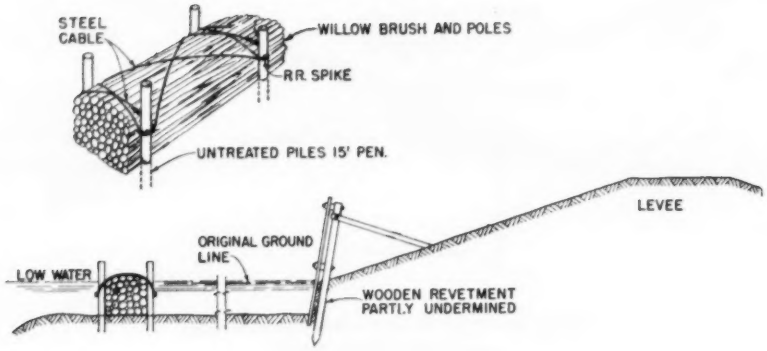

Fig. 9. Brush Dike Built to Prevent Undermining

Fig. 10. A Brush Dike on the Mississippi River

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